DOCUMENT RESUME

ED 350 152 SE 052 949

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TITLE Analogies in Secondary Chemistry Education Textbooks: The Authors' Views.
PUB DATE 18 Oct 91
NOTE 12p.; Paper presented at the Annual Meeting of the Western Australian Science Education Association (16th, Perth, Western Australia, Australia, October 18, 1991).
PUB TYPE Viewpoints (Opinion/Position Papers, Essays, etc.) (120)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Authors; Chemistry; *Educational Research; Foreign Countries; *Interviews; Science Education; *Science Instruction; Secondary Education; *Secondary School Science; *Textbooks
IDENTIFIERS Analogies; *Analogy; Australia

ABSTRACT

Recent studies in education have indicated that analogies are occasionally included in chemistry textbooks in an attempt to help students' understanding of abstract chemical concepts and sub-microscopic structures. This paper reports on a study in which authors of major textbooks currently used in Australian schools were interviewed to ascertain their views on the use of analogies in chemistry education. The authors indicated that they are generally unwilling to set analogy into print because of a belief that analogies should involve discussion and negotiation with students which is not possible in a textbook situation. Those authors who employed analogies sparingly in their textbooks, tend to focus on analogy as a visualization tool and, to a lesser degree, a way of communicating abstract ideas via the students' own language and experience. Alternatively, those authors employing analogies more frequently in their textbooks, tend to see analogies more as motivational tools. It is concluded that the unfamiliarity of textbook authors with research guidelines regarding analogy presentation highlights the problems of the efficient dissemination of research findings in science education to practitioners. (Contains 10 references.) (PR)

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Analogies in Secondary Chemistry Education Textbooks: The Authors' Views.

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Recent studies in chemistry education have indicated that analogies are occasionally included in chemistry textbooks in an attempt to aid the students' understanding of abstract chemical concepts and sub-microscopic structures. However, the frequency of analogy inclusion varies markedly between textbooks. In addition, most analogies found in textbooks used by Australian high school chemistry students tend not to be in accordance with the recommendations made in a decade of research literature relating to the most effective use of analogies in science education.

This paper reports on a recent study in which authors of major textbooks currently used in Australian schools were interviewed to ascertain their views on the use of analogies in chemistry education. The authors indicated that they are generally unwilling to set analogy into print because of a belief that analogies should involve discussion and negotiation with students which is not possible in a textbook situation. Those authors who employed analogies sparingly in their textbooks, tended to focus on analogy as a visualization tool and, to a lesser degree, a way of communicating abstract ideas via the students' own language and experience. Alternatively, those authors employing analogies more frequently in their textbooks, tended to see analogies more as motivational tools.

In addition, each author was questioned concerning different styles of analogy presentation and on the knowledge of, and approach toward, a six stage model specifically designed to assist textbook authors in analogy presentation. Finally, the views of the authors were sought concerning their response to the researcher's intent to produce a bank of trialled analogies for inclusion in chemistry textbooks and teachers' guides as well as for use during classroom instruction by practicing teachers.

INTRODUCTION

Recently, there has been a growing interest in how teachers use various strategies to arrange and present the content under study in a meaningful way that will enhance learning for understanding. This focus on the teachers' subject specific pedagogical content knowledge includes various finer aspects of instruction, one of which is analogy. Analogy is a tool that is used by teachers to assist in the explanation of abstract concepts. The sub-microscopic nature of much of the content of chemistry suggests that analogies may be used more frequently in this subject than others of a more visual nature.

Indeed, in an examination of 26 high school science textbooks in the United States, Curtis and Reigeluth (1984) found that the chemistry textbooks contained more analogies than other sciences such as biology, physics, and general science. In a later study, it was also shown that science textbooks in general contained considerably more analogies than social studies textbooks (Curtis, 1988). In a recent study, Thiele and Treagust (1991) conducted an analysis of 70 analogies identified in eight chemistry textbooks used in Australian secondary schools and reported that the chemistry content area also markedly influenced the frequency of analogy use. The

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findings of that study suggested that analogies were included most often for the topics of Atomic Structure (23%), Energy (14%), and Bonding (10%). This adds further credence to the assertion that analogies are used more frequently when the content is more abstract or sub-microscopic in nature.

That study also highlighted the inconsistency with which analogies have been included in various textbooks with four of the eight textbooks having only between one and five different analogies whilst the other four textbooks contained between 12 and 17 different analogies. However, despite the marked variation in popularity, no research has been reported as to why authors choose to include or omit well known or other analogies in their textbooks. Indeed, if analogies are useful in explaining abstract chemistry concepts in student world language, then it would be expected that there be more uniformity amongst their frequency of use. Alternatively, if authors consider that analogy is not an appropriate tool for inclusion in textual material for students, due to their many stated limitations (Webb, 1985), why are they included at all?

In addition to the areas of concern stated above, a decade of research into the use of analogies has provided some theoretical perspectives of the profile that a successful analogy should adopt. For example, both Glynn et al. (1989) and Zeitoun (1984) have presented model approaches to analogy teaching and the inclusion of analogies in textual materials. Whilst these reports are more recent than the textbooks under study, it is important to consider the possibility that the implications of these studies are not reaching curriculum designers. If this is the case, then we can expect that future editions of textbooks by these, and other, authors shall continue to present analogies in what some researchers (e.g. Curtis & Reigeluth, 1984; Duit, 1990; Glynn et al., 1989; Thiele & Treagust, 1991; Webb, 1985) consider to be a less than efficient manner.

RESEARCH FOCUS

The purpose of this study was to determine, from interviews with the authors of the textbooks examined in the earlier study, the awareness of, and attitudes towards, the use of analogies in textbooks for secondary school chemistry students.

The interview questions that were addressed in this study are as follows:

1. What are the views currently held by textbook authors concerning analogy usage?
2. What reasons are given for inclusion or exclusion of analogies in instructional materials?
3. What personal appeal is there to a model approach for analogy teaching such as the Teaching With Analogies (T.W.A.) model (Glynn et al., 1989) or the General Model for Analogy Teaching (G.M.A.T.) (Zeitoun, 1984)?
4. Why are analogies occasionally presented in the margins of the page rather than embedded into the text?
5. What changes would the author make to a later edition of their own textbook or teachers' guide if they were given a more thorough repertoire of trialled, familiar analogies?

METHOD

Semi-structured interviews were conducted with five authors who will be referred to as Authors A, B, C, D, and E. These five authors represent six of the eight textbooks. Of the remaining two textbooks, one of the authors was no longer in a position to be involved due to failing health and the other will be interviewed next year as he is overseas at present.

The interviews were conducted in the semi-structured manner suggested by Yin (1989). Four of the five interviews lasted approximately 80 minutes and were conducted in person. The other interview (with Author E) was conducted via a long distance telephone conversation which was tape recorded with his permission. During the interviews, examples of analogies used in the author's own textbook were used, wherever possible, to focus discussion and to assist in the definition of terms used by the interviewer and interviewees. All of the interviews were tape recorded and transcripts were produced. The researcher then considered the transcripts in an interpretive manner (Erickson, 1986) to address the research questions. At this stage, further reflective observations were provided by a colleague.

The results of the earlier study (Thiele & Treagust, 1991) indicated that both Authors A and E used analogies more frequently (17 and 14 analogies respectively) whilst the textbooks represented by the other three authors contained between one and five analogies. However, the textbook by Author E contained almost four times as many words as the other textbooks and, on an analogy by size consideration, can be considered to contain less analogies.

FINDINGS

On the authors' background

Since the academic and educational involvement of the authors may substantially influence their approach to analogy, data were collected concerning their backgrounds in these respects. All five of the authors held PhDs in chemistry completed at early stages of their chemistry education experience. Three of the five (B, C, and D) had completed formal education studies at either graduate diploma level and/or Masters level. Two of the authors (B and C) had experience teaching secondary chemistry prior to their involvement in their respective textbooks, one of whom (B) also had tertiary education experience in the areas of chemistry and science education and was no longer a practicing high school teacher at the time that the textbook was written. The other two authors (A, D, and E) each had had considerable experience as chemistry educators at the tertiary level with emphases in chemistry for undergraduates. Figure 1 more fully profiles the differences in the authors' backgrounds at the time that they wrote their respective textbooks.

Beginnings of textbook involvement

All five of the authors had been involved in some aspect of curriculum development prior to their work with the textbooks. Three had some prior experience in the writing of laboratory manuals for senior chemistry students and three of them (B, C, and E) had been involved in writing text materials for larger scale curriculum initiatives. One of the authors (B) indicated that he had completed a postgraduate unit on curriculum development and that it had always been a desire of his to take a significant role in the production of a textbook. Similarly, Author E

indicated that he had an interest in presenting concepts in written form that link together various aspects of the discipline of chemistry.

On the characteristics of a good chemistry teacher

It was hoped that this question might uncover any leaning towards a pedagogical style that would be particularly conducive or otherwise towards the use of analogies.

Four of the five authors (B, C, D, and E) strongly emphasized that the need for a strong background in chemistry was by far the most important factor. Comments, such as that of author E, about the requirement of a teacher to be "totally on top of the discipline aspect", and by Author D, of the need for a content knowledge "way in advance of the level you are teaching" as being "the only way that you can have comfortableness, enthusiasm, imaginative ideas, different ways of presenting things" suggests that these authors consider that ease of teacher style can be best set upon a foundation of good content knowledge. Having established this foundation, the authors tended to list some personal relationship characteristics of teachers such as their being interested in students, able to suitably organise and select the content, empathetic, compassionate, sensitive, and enthusiastic. The teacher having a sense of humour was also considered favourably.

The other author (A) more strongly expressed opinions that were kindred to the student-teacher relationship stressing the need for the teacher to be interested in the thought processes of students, and to be "clear and precise, be fair, and be prepared to admit that you are wrong."

Author	A	B	C	D	E
Academic (Chem)	PhD (Chem)	PhD (Chem)	PhD (Chem)	PhD (Chem)	PhD (Chem)
Academic (Educ)	-	Masters	Masters	B. Ed	-
Experience (secondary)	-	4 yrs	13 yrs	-	-
Experience (tertiary)	30 yrs	5 yrs	-	15 yrs	20 yrs
Prior development	1 text	lab guide	-	lab guide 1 text	1 text

Figure 1. Profile of authors' backgrounds at the time of writing.

On the meaning of analogy

The authors' ideas of what did, and what did not, constitute an analogy, indicated general agreement with each other and the researcher. Some variances in the discussion however, followed the lines of "all science is analogy" due to the use of symbolizes in instruction and descriptions of invisible processes and entities

(Author C). One of the authors (D) discussed and demonstrated what could be described as a rice analogy for particle theory relating to the states of matter. It was agreed that this demonstration, although being analogical in nature, could better be described as an analog model. The authors demonstrated that they did not confuse examples with analogies and they were able to clearly identify two discrete domains in the analogies that were discussed.

Examples of analogies used in their own teaching

This question was asked in the anticipation that insight may be obtained as to the authors' personal views of analogies in teaching so that a comparison may be made to the frequency of analogy inclusion in the textbook.

Four of the authors (A, B, C, and D) conveyed some difficulty recalling analogies that they had used in their teaching. Author E was able to instantly respond with an analogy that he had recently used in a teaching situation. However, this author had some prior warning of the questions due to the nature of the telephone interview arrangements. The analogy that Author E recounted was one in which the target concept was the apparent movement of a positive charge through a semi-conductor as electrons move between semi-conductor "holes" when under the influence of an electric field. The analog for this system was the ionic proton transfer mechanism that ocurres when an electric current is passed through a hydroxide solution. The protons jumping between hydroxide ions contribute a substantial proportion to the total conductivity of the hydroxide ion.

One of the authors (C) gave an example of the pole-vaulting analogy for activation energy and catalysis which he had adopted having seen it on an I.C.I. chemistry education film entitled "Catalysis".

Other authors (B and D) proposed analogies relating to electronic behavior - the ladder steps analogy for energy levels and the models of vibrating strings, plates, and water waves for energy quanta. Author B further proposed analogies from his contact with the Chem Study films and textbooks. These analogies included the mountain pass analogy for catalysis and the goldfish (in the dumbbell-shaped bowl) analogy for chemical equilibrium. This author suggested that he did not use analogies as frequently now as what he had done at the time when he was teaching chemistry using the Chem Study curricular materials and, in explanation, he commented that he was well aware of the research indicating that some of these analogies may result in the students forming misconceptions.

One of the authors (A) indicated several analogies that were in his textbook that he used in his teaching also. He suggested that the analogies lost something when they went to print because, when using them in the classroom, they could be presented in such a way as to foster interest and motivation more readily. However he, like the others, indicated that analogy was something of a spontaneous exercise and that they were more likely to use analogies when attempting to explain an abstract idea to students after the student had indicated that they did not clearly understand. For example, author C commented that "analogy is a very personal thing, something you might deal with on a one to one basis."

In a similar manner, all of the authors seemed to be aware that there was a need for analogies to be discussed by both teachers and students when they are used in a classroom setting. Having described his analogy for the semi-conductor, Author E

commented that the analogy had been created spontaneously by him as a result of being questioned concerning the target concept by some students after a lecture. In this situation, he could "push it [the analogy] to outrageous lengths, then, when they've seen the point, you can, sort of, throw the analogy away and come back to the point you are trying to make." Author C suggested that when using analogies on the whole class scale, that he would build the analogy and then destroy it to illustrate where the analogy broke down. He proposed that the instructional value was in the resulting discussion and evaluation of the unshared attributes rather than in the construction or presentation of the analogy. Author B, when questioned concerning a particularly problematic analogy for chemical equilibrium commented that "maybe the way to deal with it is to point out what's wrong with the model." Later, concerning the same analogy, he suggested that "I wouldn't mind using it myself if I had control of the situation in a classroom situation" but he went on to indicate the lack of control available once the analogy is in textbook form by adding "but I wouldn't like to stick it in a text where everybody is going to use it."

This theme of the inability to negotiate analogy once it is in text was taken up by several of the authors. For example, Author A commented that "many analogies work much better in the teaching situation than they do as presented in books." Author B felt likewise and suggested that he preferred to use them himself "rather than put them in written form .... I don't really want to lock an analogy into concrete." Author E, commenting from a similar viewpoint, proposed that:

> I guess I'm a little wary about the use of analogies by writing them down in the sense that, if you put them in a textbook, ... there is a bit of a danger that students can get the analogy confused with the reality. That's not true in every case obviously, but my experience has been that analogy can work very well indeed but not for everybody. The analogy that works for student A is lost on student B and I rather like using analogies in a situation where I don't have to commit myself. I can say much looser things than I would really want to commit to paper when I am arguing analogically with a student.

Similarly, Author C responded that "I would be reluctant to use an analogy in a textbook because I don't know that you could ever, in words, provide an adequate representation for all students." Later, he emphasized that when you are teaching you can respond to those students who do not understand the concept by an analogy or further explanation but that "you don't see the blank faces of the students you are writing the text for."

On student understanding of analogies

Often, comments were made by the authors concerning the interactions that the students might have with the analogy and the process of analogy. When asked why he decided to include a particular analogy in his text, author D responded in terms of traditionally accepted advantages for analogy inclusion by stating:

> I guess two things. One is that it gives the student something to relate to. The other one is that analogies, I suppose, are most likely to be used when we are talking about the sub-microscopic level and they can't see them (can't see the particles that we are talking about) and so we use an analogy that is in our experience, that is ... *something we can relate to and can visualize* [italics added] and then try to take back.

Author C, focussing on the first of these ideas, remarked that we use analogy "to help put something into a language that the students can understand ... to make the complex commonplace." It is interesting that these authors have identified the 'visualization' advantage and the 'student world' advantage, yet not the 'motivational' advantage of analogy. It is also interesting that author D considered that the analogy should be in "our" experience and as being something that "we" can relate to. This is important when compared to the comments of author C who, reflecting back on some research he conducted in classrooms recalled a student making the statement:

> Analogies are very personal things. What's a good analogy for Mr X is not a good analogy for me because I don't think the same way that Mr X does. It's alright for Mr X - he knows the whole story. I don't! You're trying to present an analogy to me when you know what all of it means. You know what is coming up and you are aware of the history behind that. Here I am, as a student in the first couple of weeks of my senior chemistry course, being thrown into this same thing. I don't know what the end of the story is like. It's like trying to use information that I am going to get in chapters 7, 8, and 9 of my novel to answer a dilemma that I have in chapter 1."

This same author (C) also acknowledged that, whilst the students' ability to deal with the analogy should not be overlooked, the need for analogies varies markedly from student to student. He believed that the need is related more to academic performance and suggested that "there's got to be some students who will need a little bit more information and there will be other students who will say 'this is pretty tedious stuff'."

Awareness of, and appeal for, Glynn's T.W.A. model

In this question, the researcher wished to ascertain which, if any, of the authors recognized Glynn et al.'s Teaching With Analogies (T.W.A.) model or were aware of any other models relating to analogy presentation (such as the G.M.A.T.). In addition, the authors were asked to comment upon their perception of the usefulness of such a model for textbook presentation of analogies after having studied it for several minutes.

It was clearly apparent that none of the authors recalled ever having seen or used a model for analogy presentation. One of the authors (C) was aware of some work done by Clement on bridging analogies in physics (Clement, 1987) but that work was not related to textbooks. Another of the authors (B) commented upon the similarity of the model to an established approach for the teaching of concepts (with attribute analysis, examples, and non-examples). Author C concluded that the model approach appeared to be "an incredibly tedious exercise" if there was not a shared authorship of the textbook. The other authors, however, appeared to accept the six step model as useful although some suggested variations and alterations with two of them (A and D) acknowledging that they considered that the best approach varied depending upon the analogy and the setting. Author E was content with the model as it was presented and indicated that it was common sense and that "most experienced teachers would do that without even being conscious that they were doing these things."

Other useful comments came from Author B who suggested that the limitations of an analogy could be presented at the same time as the similarities - that is, before the

conclusions are drawn. Author D attempted to clarify the conflict that arises over the use of an analogy to draw conclusions rather than to confirm a previously arrived at conclusion by remarking that:

> There certainly must be cases in where [*sic*] the conclusion has already been made and, in an attempt to make sense of that conclusion, you might use the analogy. Though, I suppose what you are at least doing is drawing out the conclusions of what you have previously done before.

The authors' comments indicate a general acceptance of the model approach for analogy presentation provided that due regard be given for flexibility in various settings.

Preferences for different positions of analogies

The authors were asked to carry out an activity in which they were to indicate where, on a page of text, they would insert a pictorial analogy with which they had been provided. This would provide some evidence to the researcher of the authors' willingness to include pictorial analogies into the textbook and their preferences for the position of such analogies in the text.

The approach to this task varied between authors with some studying the text at length whilst others skimmed the text and focussed more carefully on the analogy. An initial response that was consistent with Authors A and D was to position the analogy in the page margin. Both of these authors had textbooks that included a substantial number of marginalized comments, diagrams, anecdotes, and some marginalized analogies. Author D, when questioned concerning a marginalized analogy in his text, had commented that:

> We didn't think it was essential to put in or else we wouldn't have put it in the margin. Those things are things that we thought anyone could use this book without even referring to. So we thought it was useful to put it in - it might have been interesting for some to put it in.

Further, on the analogy task that Author D was attempting, he commented that:

> You put it off to the side because it's something you could elude to and is maybe useful but it doesn't interfere with the flow and it's not necessary for the flow and not everyone would need it but it's there if you want to go that way.

Two other authors (B and C) initially chose to put the analogy at the start of the text as an advance organizer. Author C's rationale for this was that, when reading their textbooks, the students tend not to look back to relate a current diagram or anecdote to an earlier mentioned concept. Author B clearly considered that the pictorial analogy could act as "a bit of an organizer" although both he and author D later changed their minds to come to a tenuous decision that it should be embedded at the point of discussion concerning the target content in the text itself. Author E had also considered that the analog should be inserted in the text at the point of target discussion. Author B analogically suggested that the placement of the analogy was similar to the positioning of laboratory work in the programme of content when he proposed that:

> You can use it just beforehand to introduce conceptual stuff, you can use it afterwards as a reinforcement thing, or you can use it separately if you are pushing some particular lab skills - lab process skills. And maybe as a general rule, seeing you are trying to use the analogy to make the thing more concrete possibly (and certainly more understandable), maybe the earlier you can get it in the better.

However, author A, defending his proposal for a separated analogy "as another illustration in the margin or halfway in a little box by itself", commented that he didn't find that presenting the analogy right at the beginning was particularly helpful. Rather, he used "analogies to solve problems rather than to pose them."

Proposed future use of a bank of trialled analogies

When asked if they would be interested in incorporating some of a bank of trialled analogies in a fictitious new edition of their texts, several of the authors indicated some reluctance. Author C categorically stated that he "wouldn't use them in the textbook" whilst Author B only agreed to the inclusion on the proviso that the "person writing the book felt comfortable." Similarly, Author E agreed that he would consider them but he would "need a fair bit of convincing that an analogy was a valid one." On further questioning, however, four authors showed particular interest in having these trialled analogies available in the form of a teachers' guide. Author E showed enthusiasm for the idea whilst Author D proposed that each analogy "could have a blurb on each of the six steps" (TWA model). In addition, Author C suggested that he "might be interested in putting them in a teachers' guide." He qualified his concession, however, by proposing that, even in a teachers' guide, there would be the need for some form of instruction to teachers that "clearly you don't just take these into the classroom cold and assume that all your students, at the end, will be enlightened."

On the authors changing perspectives on analogy

Two authors (B and C) have both been active recently in conducting educational research in science classrooms. Both of them commented that their ideas on student understanding and student learning had been significantly affected by their findings and that this would also have altered their perspective on the students' use and understanding of analogies. Author C, in his closing remarks in the interview, commented upon these changes thus:

> My opinions of analogy, my notion of how powerful and useful it is, have evolved considerably in the last two years. Had you been talking to me two years ago, you certainly would have got quite a different set of answers.

The comments of these two authors could indicate that closer examinations of the difficulties that some students have in understanding abstract concepts makes a teacher more wary concerning the use of tools such as models an analogies due to the risk of misunderstanding or confusion.

DISCUSSION

The present study has highlighted differences in the authors' approach to analogy that may explain the variations in the frequency of analogy inclusion in the textbooks examined in an earlier study (Thiele & Treagust, 1991).

Concerning the general views of the authors to the inclusion of analogies in textbooks, the authors generally felt uncomfortable about setting analogies into print as they lose the sense of control and flexibility that the authors consider is required by the teacher. Most consider that analogy should be used by teachers as a negotiated response strategy to be used when the teacher considers that explanations to the student of a particular concept have been unsuccessful.

The authors were able to identify the main advantages of analogy use as being a) the provision of 'student world' reality, b) improving the visualization process, and c) improving student motivation. Those authors who have used analogies infrequently in their textbooks did not tend to identify the latter as a valid use of analogies.

The authors were not familiar with any models that guided analogy presentation in textbooks or in teaching. However, upon presentation of such a model, most of the authors suggested that it would be a useful model although they expressed a desire to have some flexibility in the order of the stages of the model.

Interviews with the authors showed that the use of analogy in the page margins of some textbooks reflects the perception of the author that the analogy is something that many students can do without and should, therefore, simply be made available to those students requiring a further explanation of the concept under study.

Those authors who had used analogies sparingly in their textbooks showed little or no inclination to include them in a later, fictitious textbook. One author, who used analogies frequently in both the textbook and in teaching, suggested that there would be no change in the future edition. The authors expressed interest in the inclusion of a bank of trialled analogies into a teachers' guides where a model such as the T.W.A. model (Glynn et al, 1989) could be used to assist teachers in their teaching with analogies.

CONCLUSIONS

The inclusion of analogies in the textbooks written by these authors reflects variations in the authors' perceptions of the advantages and disadvantages of analogy use as well as reflecting variations in their respective backgrounds. Those authors who had undergone formal study in teaching and education tended to include and use analogies less frequently. However, the frequency of analogy inclusion in the textbooks does not seem to be indicative of the willingness of the authors to use analogy in their own teaching. Rather, they are unwilling to set the analogy to print because of their belief that teaching with analogies should involve discussion or negotiation with the students. This is not possible in a textbook situation.

The unfamiliarity of the authors with research guidelines regarding analogy presentation highlights the problems of the efficient dissemination of research findings in science education to practitioners. However, the willingness of the authors to accept a model approach to analogy, all be it a more flexible one, indicates the usefulness of such an approach. Also, it should be considered that there is still a lack of empirical research findings suggesting that analogy presented in the model format aids student understanding more than other analogies.

Although being generally against the inclusion of analogies in student textbook materials, those interviewed authors expressed an interest in the inclusion of analogies into teachers' guide materials. This is an area to be addressed by the researcher in future work.

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